

SPECIFICATION

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[JET COOLED X-RAY TUBE WINDOW]

Cross Reference to Related Applications

The present invention is related to U.S. Patent No. 6,215,852 B1 entitled "Thermal Energy Storage and Transfer Assembly", which is incorporated by reference herein.

Background of Invention

[0001] The present invention relates generally to thermal energy management systems within electron beam generating devices, and more particularly, to an assembly for cooling an x-ray tube window.

[0002] There is a continuous effort to increase x-ray imaging system scanning capabilities. This is especially true in computed tomography (CT) imaging systems. Customers desire the ability to perform longer scans at high power levels. The increase in scan time at high power levels allows physicians to gather CT images and constructions in a matter of seconds rather than several minutes as with previous CT imaging systems. Although the increase in imaging speed provides improved imaging capability, it causes new constraints and requirements for the functionality of the CT imaging systems.

[0003] CT imaging systems include a gantry that rotates at various speeds in order to create a 360 ° image. The gantry contains a x-ray tube, which composes a large portion of the rotating gantry mass. The CT tube generates x-rays across a vacuum gap between a cathode and an anode. In order to generate the x-rays, a large voltage potential is created across the vacuum gap allowing electrons to be emitted, in the form of an electron beam, from the cathode to a target within the anode. In releasing of the electrons, a filament contained within the cathode is heated to incandescence

outlet. The coolant outlet directs coolant at an x-ray tube window surface to impinge upon and cool the x-ray tube window. The coolant is reflected off the reflection surface as to impinge upon and cool the x-ray tube window. A method of operating the x-ray tube is also provided.

[0011] The present invention has several advantages over existing x-ray tube cooling systems. One of several advantages of the present invention is that it provides an apparatus for directing coolant at an x-ray tube window. By directing coolant at the x-ray tube window the window is efficiently cooled, deposit formation on the window is minimized, and deposits are washed away as soon as they are formed, thus minimizing blurring and artifacts in a reconstructed image.

[0012] Another advantage of the present invention is that it provides a cooling mechanism or fin pocket, which effectively removes thermal energy from the coolant. The fin pocket is located on a coolant side of the electron collector body, providing relative ease in manufacturing of the present invention.

[0013] Furthermore, the present invention provides additional x-ray tube window cooling via an auxiliary cooling circuit, further allowing for increased scanning speed and operating power, while being able to effectively cool the x-ray tube window.

[0014] The present invention itself, together with attendant advantages, will be best understood by reference to the following detailed description, taken in conjunction with the accompanying figures.

Brief Description of Drawings

[0015] For a more complete understanding of this invention reference should now be had to the embodiments illustrated in greater detail in the accompanying figures and described below by way of examples of the invention wherein:

[0016] Figure 1 is a schematic block diagrammatic view of a multi-slice CT imaging system utilizing an x-ray tube window cooling assembly in accordance with an embodiment of the present invention;

[0017] Figure 2 is a perspective view of a x-ray tube assembly incorporating the x-ray tube window cooling assembly in accordance with an embodiment of the present

invention;

[0018] Figure 3 is a sectional perspective view of an x-ray tube incorporating the x-ray tube window cooling assembly in accordance with an embodiment of the present invention;

[0019] Figure 4 is a close-up sectional perspective view of the x-ray tube incorporating the x-ray tube window cooling assembly in accordance with an embodiment of the present invention;

[0020] Figure 5 is a top view of the x-ray tube window cooling assembly in accordance with an embodiment of the present invention;

[0021] Figure 6 is a front view of the x-ray tube window cooling assembly in accordance with an embodiment of the present invention;

[0022] and Figure 7 is a logic flow diagram illustrating a method of operating an x-ray generating device in accordance with an embodiment of the present invention.

Detailed Description

[0023] While the present invention is described with respect to an assembly for cooling an x-ray tube window within a computed tomography (CT) imaging system, the following apparatus and method is capable of being adapted for various purposes and is not limited to the following applications: MRI systems, CT systems, radiotherapy systems, flourosocopy systems, X-ray imaging systems, ultrasound systems, vascular imaging systems, nuclear imaging systems, magnetic resonance spectroscopy systems, and other applications known in the art.

[0024] In the following description, various operating parameters and components are described for one constructed embodiment. These specific parameters and components are included as examples and are not meant to be limiting.

[0025] Also, in the following description the term "impinge" refers to an object colliding directly with another object. For example, as known in the art, an electron beam impinges upon a target of an anode within an x-ray tube. The electron beam is directed at the target and electrons within the beam collide with the target. Similarly, a

coolant may be directed at a surface as to collide with the surface. The coolant in being directed at a surface and may be reflected from another surface. The term "impinge" does not refer to an object simply coming into contact with another object, such as coolant flowing over a surface of an object.

[0026] Referring now to Figure 1, a schematic block diagrammatic view of a multi-slice CT imaging system 10 utilizing an x-ray tube window cooling assembly 11 in accordance with an embodiment of the present invention is shown. The imaging system 10 includes a gantry 12 that has an x-ray tube assembly 14 and a detector array 16. The x-ray tube assembly 14 has an x-ray generating device or x-ray tube 18. The tube 18 projects a beam of x-rays 20 towards the detector array 16. The tube 18 and the detector array 16 rotate about an operably translatable table 22. The table 22 is translated along a z-axis between the assembly 14 and the detector array 16 to perform a helical scan. The beam 20 after passing through a medical patient 24, within a patient bore 26, is detected at the detector array 16 to generate projection data that is used to create a CT image.

[0027] The tube 18 and the detector array 16 rotate about a center axis 28. The beam 20 is received by multiple detector elements 30. Each detector element 30 generates an electrical signal corresponding to intensity of an impinging x-ray beam. As the beam 20 passes through the patient 24 the beam 20 is attenuated. Rotation of gantry 12 and the operation of tube 18 are governed by a control mechanism 32. Control mechanism 32 includes an x-ray controller 34 that provides power and timing signals to the tube 18 and a gantry motor controller 36 that controls the rotational speed and position of gantry 12. A data acquisition system (DAS) 38 samples analog data from the detector elements 30 and converts the analog data to digital signals for subsequent processing. An image reconstructor 40 receives sampled and digitized x-ray data from the DAS 38 and performs high-speed image reconstruction. A main controller or computer 42 stores the CT image in a mass storage device 44.

[0028] The computer 42 also receives commands and scanning parameters from an operator via an operator console 46. A display 48 allows the operator to observe the reconstructed image and other data from the computer 42. The operator supplied commands and parameters are used by the computer 42 in operation of the DAS 38,

the x-ray controller 34, and the gantry motor controller 36. In addition, the computer 42 operates a table motor controller 50, which translates the table 22 to position patient 24 in gantry 12.

[0029] The x-ray controller 34, the gantry motor controller 36, the image reconstructor 40, the computer 42, and the table motor controller 50 are preferably microprocessor-based such as a computer having a central processing unit, memory (RAM and/or ROM), and associated input and output buses. The x-ray controller 34, the gantry motor controller 36, the image reconstructor 40, the computer 42, and the table motor controller 50 may be a portion of a central control unit or may each be stand-alone components as shown.

[0030] Referring not to Figure 2, a perspective view of the x-ray tube assembly 14 incorporating the cooling assembly 11 in accordance with an embodiment of the present invention is shown. The tube assembly 14 includes a housing unit 52 having a coolant pump 54, an anode end 56, a cathode end 58, and a center section 60 positioned between the anode end 56 and cathode end 58, which contains the x-ray tube 18. The x-ray tube 18 is enclosed in a fluid chamber 62 within lead-lined casing 64. The chamber 62 is typically filled with fluid, such as dielectric oil, but other fluids including water or air may be utilized. The fluid circulates through housing 52 to cool the x-ray tube 18 and may insulate casing 64 from high electrical charges within the x-ray tube 18. A radiator 68 for cooling fluid 66 is positioned to one side of the center section 60 and may have fans 70 and 72 operatively connected to the radiator 68 for providing cooling air flow over the radiator 68. Pump 54 is provided to circulate fluid 66 through housing 52, through radiator 68, and through the cooling assembly 11. Electrical connections in communication with the x-ray tube 18 are provided through an anode receptacle 74 and a cathode receptacle 76. A casing window 78 is provided for x-ray emission from the casing 64.

[0031] Referring now to Figures 3 and 4, sectional perspective views of the x-ray tube 18 incorporating the cooling assembly 11 in accordance with an embodiment of the present invention is shown. The x-ray tube 18 includes a rotating anode 80, having a target 82, and a cathode assembly 84 disposed in a vacuum within vessel 86. The cooling assembly 11 is interposed between the anode 80 and the cathode 84.

enters the first channel 116 via a first external tube 132 coupled over an opening 134 in a collector exterior surface 136 of the collector 110. In the embodiment of Figure 3 and 4, the vessel exterior surface 138 is flush with the collector surface 136. In another embodiment of the present invention, as illustrated by Figures 4 and 5, when the collector 110 protrudes from the vessel 86, a second external tube 140 may be attached on a lower side 142 of the collector 110.

[0037] The fin pocket 118 is located within a single wall 144 of the collector 110 above the window 104. By having the fin pocket 118 only on the coolant side 126, risk of vacuum leak is minimized since the fins 124 are not brazed to a side of the collector that is on the vacuum side 128, as there are in prior art thermal energy storage devices. When fins are brazed into a side of a collector, seams are created, which can develop leaks over time. The present invention by incorporating the fins in a single wall 144 of the collector 110, eliminates the seams within the collector 110, on the vacuum side 128, resulting in less potential for vacuum leaks. Although, the fin pocket 118 may be on multiple sides of the collector 110 and may be in multiple locations, by having the fin pocket located as stated the present invention provides simplicity in manufacturing while maintaining efficient thermal transfer. Although, multiple cooling fins 124 are shown as lanced offset cooling fins, other style cooling fins, or high efficiency extended cooling surfaces known in the art may be used.

[0038] The outlet 122 directs coolant at a reflection surface 146 on the x-ray tube 118. The reflection surface 146 may be a portion of a transmissive device 148 of the casing 64, as shown, may be an internal casing wall surface 150, or other deflecting surface known in the art. The reflection surface 146 is located opposite that of an x-ray tube window surface 152, with a gap 153 therebetween. Coolant 130 passing through the fin pocket 118 is directed from the outlet 122 to reflect off the reflection surface 146 as to impinge upon and cool the window 104. The gap 153 may be of various width and may be adjusted such that the coolant 130 impinges appropriately on the window 104.

[0039] The outlet 122 has an opening 154 with a cross-sectional area that is smaller relative to cross-sectional area of said fin pocket 118, perpendicular to direction of coolant flow, such that as coolant 130 is passed from the fin pocket 118 through the

outlet 122, velocity of the coolant 130 increases. By increasing coolant velocity, the outlet 122 in conjunction with the fin pocket 118 performs as a coolant jet, which further aids in cooling the window 104. Also, opening width 156 of the outlet 122 is approximately equal to window width 158 of the window 104, such that coolant 130 impinges across width of and provides uniform cooling of the window 104.

[0040] A guide 160 may be incorporated to aid in direction of the coolant 130. The guide 160 also has similar width 162 to that of the opening width 156 and width 158. The guide 160 may be in various form, size, and style. The guide 160 may protrude from the collector 110, as shown, or may be incorporated within the collector 110 as to be more flush with the collector exterior surface 164.

[0041] The transmissive device 148 is in the form of a transmissive window allowing the x-rays 96 to pass through the casing 64. The transmissive device 148 may be formed of aluminum or other material known in the art.

[0042] A second coolant circuit 166 may be incorporated within the cooling assembly 11 including an auxiliary coolant jet 168 directing additional coolant 170 to flow across the window surface 152, as best seen in Figure 5. The auxiliary jet 168 is preferably directing coolant 170 in the same direction as flow of current 130 from the outlet 122 to increase current flow, rather than restrict current flow, and thus, increasing cooling of the window 104. The auxiliary jet 168 may be in various locations and have various orientations.

[0043] The cooling circuits 112 and 166 may receive coolant 130 from the pump 54, via a separate pump, or some other coolant source as known in the art.

[0044] Referring now to Figure 7, a logic flow diagram illustrating a method of operating the x-ray tube 18 in accordance with an embodiment of the present invention is shown.

[0045] In step 180, the electron beam 90 is generated as stated above.

[0046] In step 182, the electron beam 90 is directed to impinge upon the target 82 as to generate the x-rays 96.

[0047] In step 184, the x-rays 96 are directed through the window 104, which increases

temperature of the window 104. Back-scattered electrons 98, from the electron beam 90, are also impinging upon the window 104 further increasing temperature of the window 104.

[0048] In step 186, coolant 130 is passed through the fin pocket 118 and is directed at the reflection surface 146, as to impinge on and cool the window 104.

[0049] In step 188, additional coolant 170 may be directed across the window 104, via the second cooling circuit 166.

[0050] The above-described steps are meant to be an illustrative example, the steps may be performed synchronously or in a different order depending upon the application.

[0051] The present invention provides an x-ray generating device window cooling system that provides improved cooling and is relatively simple to manufacture. Coolant is directed at and across an x-ray tube window preventing generation of deposits and decreasing dwell time of oil on the window, thus preventing oil sludge build-up. The window is efficiently cooled and deposits that exist are separated from the window and washed away, thus minimizing blurring and artifacts in a reconstructed image. Elimination of cooling pockets on the vacuum side of a thermal energy storage device reduces opportunity for leaks and particle contamination.

[0052] The above-described apparatus and method, to one skilled in the art, is capable of being adapted for various applications and systems known in the art. The above-described invention can also be varied without deviating from the true scope of the invention.